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Chemical and Biological Defense Systems

DARPA has keen interest in developing systems and architectures to defend buildings against attack by chemical and biological weapons. Force protection, especially protection of people in key buildings, is the immune building driver. Experience shows us that buildings have been favored targets of terrorists, both to cause damage and to make deadly statements against the United States.

The events of September 11 were another in a series of attacks using explosives and other energetic materials stretching back over several decades. Also last fall, we experienced the first widespread attacks using a biological agent, which resulted in anthrax exposures along the East Coast from Florida to Connecticut. The anthrax letters resulted in several deaths as well as extensive contamination in the U.S. Postal Service facilities where they were handled, the buildings where they were opened, and others that received cross-contaminated mail causing extensive disruption across several cities.

The Immune Building Program is part of DARPA's strategy to do as much as possible to defend buildings against a chemical or biological attack as early as possible. In this program, we look for ways to protect buildings using an active approach to neutralize or capture agents before they can do any harm. The challenging threat represented by an internal release is the main focus of the DARPA program. The overall goal is to make military buildings far less attractive targets for chemical or biological attack by modifying HVAC and other infrastructure of buildings. More on that later.

We expect to achieve this overarching goal by meeting three objectives:

- We want to protect occupants by greatly reducing exposure to whatever agent is released to below-lethal levels, if possible, or to more easily treatable levels.
- We want to restore the building to operation quickly after an attack because simply preventing a building from being used provides some measure of success to the attacker.
- We want to preserve forensic evidence from the attack for information to treat victims, if necessary, and for attribution and future retaliation.

There are four levels of operation for a notional protection architecture. In "normal" operation, the air in a building will be continuously filtered in a passive mode so any chemical or biological agent is captured as soon as it arrives at the filters. Continuous filtration has the additional benefit of providing a clean background for sensors. Tom McCreery will discuss sensors further in the next briefing, but for now note that the fastest sensors are those that simply detect the presence of biomass without being able to distinguish whether that biomass is a biowarfare agent or a naturally occurring substance such as skin cells, pollen, or mold.

Since the filters normally maintain a low background level of biomass in the air, any sudden rise in internal concentration, such as might accompany a biological attack, is suspicious and sufficient to switch the building into a "precautionary" mode. In this mode, techniques that are not appropriate for full-time, continuous operation might be used. For instance, we might choose to turn on high-power ultraviolet lamps to kill any bioagent in the return air ducts even though we would not use these lamps continuously because of concerns about operational cost.

In addition, we expect to actively manage the airflow within the building to prevent the spread of contamination as much as possible. This raises many systems issues that I will come back to. The precautionary stage lasts as long as required to get an accurate reading from a confirming sensor.

If the building is not under attack, it returns to normal mode without the building occupants ever having been disturbed, an important consideration given the performance of today's sensors.

If the attack is real, a "full-scale" response is activated; people are moved to safer parts of the building or outdoors, and all possible techniques are used to neutralize the agent at its source, including techniques that would be toxic to the occupants if they are still in the release area.

The fourth level is the post-event clean up or decontamination and collection of forensic evidence.

At the last DARPATech, we discussed two parts of the Immune Building Program: technology development and integrated system experimentation. In the technology development portion, we are investing in component technologies to provide neutralization and filtration capabilities such as those I just described. In addition, decontamination is a special concern because many portions of a building are difficult to reach; for example, ducts, plenums, the spaces between walls, and so on. These areas must be cleaned of residual contamination before the building is reoccupied, and they are not well-suited to foams, sprays, or any other technique that requires topical application.

For this reason, we have invested in development of chlorine dioxide gas for building decontamination. The gas will flow into all the areas exposed to an agent where it will neutralize the residual contamination. We have shown that chlorine dioxide kills anthrax spores very effectively with minimal residual damage to the building furnishings. We are now addressing the practical issues associated with safely pumping large buildings full of this toxic gas.

Although we have more work to do in this area, the use of chlorine dioxide gas for building decontamination has already had its first large-scale demonstration. It was selected by the Environmental Protection Agency to decontaminate the Hart Senate Office Building after the Daschle letter was opened there. We are optimistic about this approach to building decontamination and look forward to transitioning it to general use.

The other area we mentioned at the last DARPATech is integrated systems. This is the part of the program where we demonstrate that the basic approach makes sense; that is, a building can respond dynamically to the sudden presence of a threat in a way that makes the attack ineffective.

Many questions remain in determining how to best put the components together into a system. Some are system-level questions. For instance, to what extent can we isolate the contamination, and what kind of sensor response and sensor spacing is required to achieve that? And there are questions about components and component interactions. For instance, how does the performance of trigger sensors vary with the level of filtration? The answers to these and similar questions will determine how to best implement protection systems and, ultimately, how much protection they can provide.

We spent the first year of the program using modeling to understand building vulnerabilities and to carry out the design trades of various protective architectures. The graph predicts how much mass of agent must be released for various protective architectures, in order to contaminate any part of a notional building. Clearly, some architectures hold the promise of enormous protection.

However, the models used to make these predictions have many shortcomings. To answer these questions with confidence, we must carry out detailed experimental investigations in full-scale buildings. We have invested in developing two such testbeds and are now entering the experimental phase. These are the first-ever prototypes of immune buildings, and they will allow us to test out our concepts and measure their effectiveness in real buildings.

There are two other parts of the Immune Building Program starting up. One is the demonstration portion. After we finish with our experimentation in the testbeds, we will be ready for a full-scale demonstration in a real military building. We're looking for military partners who would like to have the world's first operational immune building. If you'd like to offer up your building, please give us a call!

The other part of the program is the Toolkit, an area in which we will be increasing our investment over the next several years. In some ways, the Toolkit is the most important leave-behind developed by the program.

The motivation for this program is not to develop a single immune building systems architecture to apply to all current and future buildings. This makes no more sense than trying to develop a one-size-fits-all HVAC system. Instead, the program is seeking to understand the capabilities offered by a variety of system architectures and component technologies. This knowledge will be captured in the Toolkit. It will be an integrated set of models and analysis tools that allow a user to carry out design trades for whatever building requires protection, accounting for the threats, constraints, and vulnerabilities specific to that situation. It will predict the performance achievable with whatever architecture the user decides to evaluate. By evaluating a series of possible architectures, the user will be able to select the system that best balances the user's needs with the building's vulnerabilities and constraints.

A critical feature of the Toolkit is that its predictions will be validated—and gathering data for the Toolkit validation is an important behind-the-scenes role for the test beds.

To develop the Toolkit, we must mature, or, in some cases, develop from scratch:

- A set of software modules that allows us to input building characteristics into the Toolkit
- Select the protective architecture for evaluation
- Identify the threat agent type and release location
- Configure and run models that calculate the fate and transport of the release
- Post-process those results into measures of effectiveness.

In the last year, we began working on the overall framework for the Toolkit and are now looking for organizations with expertise in developing some of the software modules I described. We are especially looking for help at the front end to determine the most efficient way to enter the building characteristics. Please come talk to us with your good ideas in this area.

So far I have spoken about building protection by mitigating the effects of an aerosolized release; especially an internal one. Consistent with our philosophy of trying to thwart an attack as early as possible, we should also think about preventing the agent from ever being released at all, something we call “portal security.”

Within this general class of protective measures are several threads we are investigating. One thing we can do is to detect and/or neutralize agents in mail, packages, and other delivered containers. Recall that last fall anthrax was delivered in letters. If we could detect the agent within a package without opening or destroying it, the package could be quarantined or decontaminated as needed. This is likely to be very difficult since all biological materials have approximately the same fundamental chemical composition. It might be easier to simply neutralize the agent using a noninvasive technique that propagates energy into the package and destroys its genome or protein structure.

Challenges to this include efficiently coupling the energy into the package through its walls, destroying the microbe without destroying the contents of nonthreatening packages, and developing a system that can handle a high throughput and a variety of package sizes.

Possibilities for achieving either the detection or neutralization goals run the spectrum from electromagnetic energy to acoustic waves to radiation. Here again we are very interested in your ideas for solving this problem.

Tiny quantities of biological agents can effectively contaminate a building and its occupants if released internally. It is necessary, therefore, to be able to effectively screen individuals and their hand-carried materials for the presence of even small amounts of biological agents as they enter a building. Various systems exist to detect trace quantities of chemical and biological materials that might be clinging to clothing or other items.

Our goal is to develop technologies to detect biological agents in sealed containers. Another aspect within portal security involves the added complexity of screening people. Because of the proximity of the person, the type and amount of energy that can be used is greatly limited.

Whether concealed on the body, carried in a briefcase, or disguised in a baby's milk bottle, we need to identify suspicious containers and nondestructively investigate them for toxic contents. We envision a system that resembles the size, speed, and intrusiveness of today's metal detectors and x-ray scanners that also performs this much more difficult task.

As you can see, we are investigating a variety of approaches for solving the difficult problems associated with protecting buildings. While expensive solutions might have only limited application at our most vital facilities, highly cost-effective approaches will be widely implemented not only at our overseas military bases, but at public and private facilities across the country.

We welcome your innovative ideas to help mitigate these deadly threats.